# THE CHARACTERS OF THE FOSSIL PLANT GIGANTOPTERIS SCHENK AND ITS OCCURRENCE IN NORTH AMERICA.

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## INTRODUCTION.

The name *Gigantopteris* has been applied to a remarkable fernlike plant from the "Lui-ho" coal field in the province of Hu-Nan, in south-central China. The specimens on which the genus was founded were discovered in 1870 at the anthracite coal mines at Lui-Pa-Koú by Baron F. von Richthofen, who, on account of the crushing throng of natives actuated by mingled curiosity and hostility, was able to gather but a small number of fossils of any kind. The striking novelty of the plant in question was at once recognized when, later, the collection was submitted to August Schenk, in Leipzig, who in 1883 described [1] the fragmentary material. The name *Megalopteris nicotianæfolia* was given to the fossil on account of the evidently great size of the leaf and the resemblance of the fragments to the leaves of the cultivated tobacco plant.

No other specimens of the kind were found in any other region or collection until 1903, when a French engineer explorer, M. Counillon, obtained a small lot of plant fragments from a coal field in the southern part of the province of Yun-Nan, which lies in southwestern China, sloping from the Himalaya Mountains and forming the northeast border of Upper Burma. These fragments were described in 1907 by Prof. R. Zeiller,[2] who regarded the flora as probably basal Triassic or possibly uppermost Permian. Schenk, who, though a high authority on Mesozoic plants, was hardly familiar with the Paleozoic floras, had as the result, perhaps, of wrong identification of some of the associated plants assigned the above-mentioned von Richthofen collection to the "coal measures." Although the fragments placed in Zeiller's hands were too small to throw much light on the nature or characters of Schenk's plant, with which the Yun-Nan material was specifically identified, they served to correct the nervation

[1] Von Richthofen, China, vol. 4, Berlin, 1883, pp. 211–269, pls. 30–54.

[2] Annales des Mines, ser. 10, vol. 11, 1907, pp. 5–27, pl. 14.

delineated in a very misleading fashion by Schenk, thus giving a truer glimpse of the unique vein system and showing more clearly the filicoid aspect of the type, the fronds of which were regarded by the distinguished French paleobotanist as probably pedalate, like those of *Clathropteris*.

The specimens described by Schenk and Zeiller are all that have been known of *Gigantopteris* until the discovery of numerous fragments at a number of localities in the "red beds" Permian of the Western Interior basin, i. e., in the Enid formation of Oklahoma[1] and the Wichita formation of Texas.

In its nomenclatural history, as well as in other respects, the genus under consideration is singular. Schenk, on learning, soon after the publication of his memoir, that the generic name *Megalopteris* had been preoccupied by Dawson[2] autographically substituted in pencil the name *Idiophyllum*, given by Lesquereux to a specimen from the coal measures (Allegheny age) at Mazon Creek, in Illinois. This name was inscribed by him in the text of the copy presented by him to Zeiller and in the copy now in the library of the United States Geological Survey. However, the original specimen described by Lesquereux as *Idiophyllum* is included in the collection presented by Mr. R. D. Lacoe, of Pittston, Pennsylvania, to the United States National Museum.[3] On reviewing the material in the Lacoe collection on the occasion of its transfer to the museum in 1893, the writer recognized in this type-specimen, which constitutes one-half of a nodule, a somewhat macerated pinna of *Neuropteris*. Several years later the other half of the nodule, the counterpart of the type-specimen, was found in the Geological Museum of Yale University by Dr. E. H. Sellards, who identified it as *Neuropteris rarinervis*,[4] thus disqualifying the name *Idiophyllum* from further use in paleobotanical literature. *Gigantopteris* was a new name penciled by Schenk, in substitution for *Megalopteris*, in the copy of his paper now in the library of Dr. H. Potonié, in Berlin, as noted by the latter in Engler and Prantl's Pflanzenfamilien,[5] where Schenk's manuscript name is for the first time put into print. Potonié places the genus among the ferns without reference to any particular group.

The American material embraces certain seeds and polleniferous (sporiferous?) scales so intimately associated with *Gigantopteris* and partaking of so many of its characters as to seem to justify placing the genus provisionally among the Cycadofilices, or Pteridosperms, rather than among the ferns.

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[1] The plant-bearing horizons of the Enid formation (U. S. Geol. Surv., W. S. Paper 154, 1906) probably fall within the Chase stage of Kansas.

[2] Geol. Surv. Canada, Foss. Plant Dev. and Upper Sil. Form., Canada, 1871, p. 50.

[3] No. 10258 of the fossil-plant collection of the U. S. National Museum.

[4] Amer. Jour. Sci., ser. 4, vol. 14, 1902, p. 203.

[5] Engler and Prantl, Natürl. Pflanzenfam., Leipzig, Teil I, Abth. 4, 1900, p. 513.

## DESCRIPTION OF THE FOSSILS.

*Localities.*—The American specimens which will be described in this paper come from the Wichita formation of Texas, the exact locality being the bank of the stream at the crossing of the old road, one-fourth mile south of the ford of Little Wichita River, 4 miles southeast of Fulda, a station in Baylor County. Here the fronds of *Gigantopteris* lie mingled with other plants in great profusion in a rather thin layer of bluish-gray friable clay shale about 3 feet above the "fish bed." The latter is a very thin, dark-colored, gnarly, bituminous limestone filled with the bones, spines, dermal plates, etc., of various fish and reptiles. It paves the road-crossing. The plant bed was first discovered by Prof. E. C. Case, of the University of Michigan, who, while collecting the vertebrate fossils [1] gathered also a few plant fragments which were kindly communicated by him to me for examination. A small collection from this most interesting locality was obtained in 1908 by Prof. C. H. Gordon and myself; and in 1909 I secured from the same locality much good plant material which, however, was largely ruined subsequently by becoming accidentally dampened.[2] On this account this collection was duplicated in 1910. The associated species will be noted, in connection with the discussion of the age of the beds, on a later page. It will suffice at this point to say that *Gigantopteris* is there mingled in a filicoid flora, with *Pecopteris*, *Tæniopteris*, *Odontopteris*, *Walchia*, *Gomphostrobus*, insect wings, *Estheria*, and fish scales. So numerous are the plant fragments and so friable and jointed are the clays that it is well nigh impossible to secure large or perfect specimens of the larger plant parts.

Besides the locality just described the genus has also been found in "Castle Hollow" 2½ miles south of Fulda; in the red sandstones three-fourths mile east of Electra, Texas, the latter locality having been discovered by Prof. Charles N. Gould, to whom geologists are indebted for the greater part of our knowledge of the "Red Beds" of Oklahoma; in the red and green shales above the thin limestone horizon about 4 miles southeast of Electra; near Perry, Oklahoma; in the vertebrate-bearing beds near Eddy, Oklahoma; and near San Angelo, in Tom Green County, Texas. In fact this curious plant is present at nearly every point where vegetable remains have been found in the Wichita formation or its equivalents in Texas and Oklahoma. Everywhere it is associated with *Tæniopteris*. On account of the very singular aspect and nervation of the leaves small pieces of *Gigantopteris* have in several instances been temporarily mistaken for fragments of some fish or reptile.

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[1] Bull. Amer. Mus. Nat. Hist., vol. 23, 1907, pp. 659, 665.

[2] The clays shrink and crack badly when dry, and melt to a paste when wet.

*The sterile fronds.*—The leaves of *Gigantopteris*, as commonly gathered, in apical or interdichotomal fragments, resemble nothing so much as portions of the broad lanceolate or linear-lanceolate leaves of some dicotyledonous genus with rather close, open, and well-defined secondary nerves. Only when the nervation is examined more closely or the dichotomy of the leaf is noted is the real nature of the plant suspected. The specific name, *nicotianæfolia*, given by Schenk to the Chinese form is therefore descriptively appropriate. When larger pieces are discovered or put together the fronds of the Texas plant are found to be broadly ribbonlike, sympodially (?) forking (pls. 43, 44, and 45) rather distantly, and slightly narrowed at the points of bifurcation, as shown in plate 43, so that the segments have a linear-lanceolate to lanceolate form. The angle of dichotomy is rather wide, generally about 60°. The lamina, which is not very thick, is generally strongly convex on the ventral surface between the secondary nerves; it is united for its whole width above each dichotomy, and is either abruptly terminated below, or gradually narrowed, while becoming lobately-incised or modified, at the base of the frond, as indicated in plate 46, figure 3, and plate 48, figure 5.

The border of the leaf is sinuate. As seen in fossils like that shown on the right in plate 45, it may be round-convex about the end of each secondary nerve; in other examples it is concave opposite the ends of the same nerves, as shown in plate 44 and plate 47, figure 1, while in still others, including the very young example, plate 46, figure 3, both phases are found. It is notable, however, that in the basal portions of the frond, in which lobation may be found, the margins are naturally convex opposite each secondary nerve, whose region of distribution corresponds to a lobe, and is in some specimens a well-defined lobe. The varying sinuosity of the margin is probably due to partial maceration and shrinkage in the lamina; convexity of outline opposite the secondary nerves is presumably the normal condition. The nervation appears to have offered greater rigidity and support for the lamina opposite the sutural nerves in the large leaves than appears to have been afforded at the ends of the secondary nerves themselves.

The nervation of *Gigantopteris* is an anomalous as well as very striking characteristic of the plant. As may be noted in the fragments shown in plates 43, 44, 45, and 47, figure 1, or even in the very young frond seen in plate 46, figure 3, the secondary nerves emerge, equidistant and parallel, at a conspicuously wide angle from the very broad, deeply depressed and irregularly lineate median nerve of the segment, and pass, ventrally depressed, nearly straight or with a slight outward turn toward the margin. They are a little decurrent at the base, and taper slightly upward to near the border where they become rapidly effaced like those of *Alethopteris*, as shown in plate 45 and plate 48, figure 1. When the lamina is slightly shrunken they appear to pass, moderately strong, to the border. The tertiary nerves originate somewhat regularly, at a wide angle, from the secondary nerves and also from the midribs in Alethopteroid fashion. They rapidly diffuse in a somewhat fasciculate system by dichotomy into slightly divergent or nearly erect, straight nervilles, some of which may fork again, as shown in plate 46, figure 2. Similar nervilles spring directly from the secondary nerves and midribs. In the older or basal portions of the large frond, like that seen in plate 46, figure 2, the tertiary nerves are more distinctly fasciculate; but in the higher areas, such as that seen in the nature print, figure 2, they are less divided, while near the apex, plate 49, figure 4, many of the nerves are simple.

As seen in all the figures, particularly plate 46, figure 2, plate 47, figure 1, plate 48, figure 2, the nerves in each fascicle tend to coalesce very obliquely with those from the next fascicle on the same side, so as to form interfascicular nerves, while all the nervilles of all the fascicles on one side of a secondary nerve, unless they have already joined the interfascicular nerves, meet with those from the near side of the next secondary nerve, and the interfascicular nerves, to form a thin sutural nerve (see nature-print, pl. 48, fig. 2) which, intermediate to the secondary nerves, and thin, passes, parallel to the latter, completely to the margin of the leaf. The lateral union of the outside nerves of the fascicule and the junction of the consequent interfascicular nerve or of the remaining nervilles with the sutural nerve effects a remarkable type of very elongated, variable, and angular areolation, as is imperfectly shown in plate 45, plate 47, figure 1, plate 46, figure 2, and plate 47, figure 2. The position and aspect of the sutural nerve reminds one of the slightly decurrent sinus between two contiguous pinnules of *Alethopteris serlii* or of *A. grandini*. So distinct is it in some fragments (pl. 48, fig. 2) and so similar the union of interfascicular nerves and nervilles to the fascicles that in small fragments it is sometimes necessary to look closely in order to ascertain which is the medial side of the lamina, and which the secondary nerve. On account of the partial maceration of the lamina in the specimens the details of the nervation are not well shown. It is, however, sufficiently indicated in plate 47, figure 2, and the nature print, plate 48, figure 2, the latter figure in natural size. The sutural nerve in these specimens appears to take the place of the parting between the pinnules of *Callipteris*. In fact the leaf is not greatly unlike a *Callipteris* in which the pinnules are completely united and the nerves confluent, in *Goniopteris* nervation, along the suture except that the veins of each fascicle tend to join the successive nerves of the next fascicle in forming interfascicular nerves which are tributary to the sutural nerves.

The semifasciculate character of the nervilles and the unique areolation in our type of *Gigantopteris* is indicated very rudely in one [1] of Schenk's figures, and it was the latter illustration which convinced me that the Chinese material is congeneric with the American, though the areolation shown in Schenk's other figures is quite incompatible therewith and probably wrong.[2] The generic agreement between the American and the Chinese plants is, however, confirmed by the nervation photographically illustrated by Zeiller from the fragments collected by the French expedition in Yun-Nan in western China, and referred by the distinguished French paleobotanist to the same species. The dichotomous mode of division of the leaf or frond is indicated by the lack of symmetry in the large fragments illustrated by Schenk.

So close is the relationship between the Chinese plant and that from Texas that I was at first disposed, on seeing Zeiller's figures, to refer it to the same species, *Gigantopteris nicotianæfolia;* but on further examination it became evident that the specimens from Fulda, described above, represent a distinct species which I therefore designate *Gigantopteris americana.* The latter is distinguished from the Von Richthofen plant by its smaller and relatively narrower and more elongated segments, which are comparatively broader at the bifurcations; by the less dentate margins; and by the generally more open and less robust secondary nerves, which usually are nearly straight or slightly down-turned, instead of distinctly turning upward as in the Hu-Nan leaf. The ultimate nervation of the American plant is possibly indistinguishable from that seen in the small fragments from western China, referred by Zeiller to Schenk's species. The Hu-Nan plant is evidently much more robust than the other, though one or two fragments nearly as broad as Schenk's broadest figure were noted in the field. In this connection mention may be made of the presence, among the fossils from Oklahoma, of a form probably specifically different from that described above.

One of the most interesting specimens in the collection is that bearing the small and probably very young leaves shown in plate 46, figure 3. In this example two small leaves appear to have originated at the base of the petiole of a larger leaf, on the left. The two little leaves come together and their midribs seem to start from a common point, but it is not certain that they coalesce. It is important to note that while the larger of the two has a short naked petiole, the smaller leaf, which is bifurcate, like the large leaves, seems to be provided with a lamina to the base. The short tooth-lobe seen on the left at the base of the blade in the larger leaf has its representation

[1] Von Richthofen, China, vol. 4, pl. 35, fig. 6.

[2] In view of the validity of the generic distinction of the types I had in manuscript already given it a name not preoccupied, when from consultation of Zeiller's paper I learned of the name penciled by Schenk in the copy used by Potonié, as already mentioned.

in many large leaves in which the tooth is prolonged into an elongated lobe. The thick basal portion of the secondary nerve of such an enlarged lobe, broken away in exposing the young leaves, is seen on the lower left of the leaf fragment shown on the right in the figure. The downward continuation of the lamina, as shown in the smallest leaf, and its lobation may have to do, I believe, with the fructification of the plant, as will presently be explained

None of the specimens yet gathered present conclusive evidence as to whether the fronds of *Gigantopteris*, seen essentially in miniature in plate 46, figure 3, were borne on an aerial axis or stem, an elongating rhizome, or in tufts. The general form of the frond and the arrangement of the leaves in the specimen suggest, however, that they may have been developed along a prostrate stem or rhizome.

*Seeds.*—At every locality where *Gigantopteris* has been found in America there are associated with it numerous flat cordiform, alate seeds at first glance suggesting *Cardiocarpon.* On closer examination the seed, which is small and obovate, is found to lie in the slightly concave face of a very broadly round-obovate, slightly cuneate and asymmetrical bract, as shown in plate 49, figure 6. The latter has in every case a narrow keel, or rib, along one of its borders, which runs down to its point of attachment, as illustrated by plate 49, figure 4. From the convex side the seed appears somewhat thickly covered by the wing or bract substance so that it is somewhat dimly outlined (plate 49, figures 3, 4, and 6); but on the concave surface it is fairly clearly defined, apparently lying beneath a thin envelope, which, in a few cases, as in the specimen shown in figure 1, is scaled off, revealing the seed itself, which appears to have a thin, hard test like that of *Cardiocarpon.* At the broader end of the seed, which is slightly apiculate, a depression or small zonulate configuration, usually accompanied by a slight gathering or puckering of the "wing," may often be noted. This, which might casually be mistaken for a chalaza, appears to lack the hardness, fiber, and all other evidence of attachment to an axis. It has the appearance of a collapsed pollen chamber, the puckered wing being susceptible of interpretation as a micropylar environment. Further, it is to be noted that a forking vascular system radiates from the base toward the broad upper end of the wing where the nerves terminate at the margin. The origin of this vascular system is clearly seen in the specimen shown in figure 2, which is still attached to its axis In this example the strands emerging from the stem or pedicel curve into the base of the wing, or bract, some of the forking bundles being clearly seen to traverse the wing. The seed seems originally to have been placed in a somewhat twisted position on the axis, the marginal rib being on the lower (proximal) side.

The nervation of the bract-wing of the seed is not clear throughout; but in most of the specimens, among the hundreds found in the collections, it may be more or less indistinctly seen branching radiately in passing to the distal margin, while in a few of the clearer examples it seems to anatomose near the distal border so as to form a mesh like the areolation of the *Gigantopteris* frond. While this areolation seems to exist, its occurrence is not, however, unquestionable. The small roundish body showing through the envelope in the upper part of the seed may be interpreted as the impression of the megaspore.

The seeds described above are provisionally referred to *Gigantopteris americana* on account of their generally abundant and most intimate association with the leaves of that plant wherever it has been found; on account of their asymmetry and solitary lateral attachment, as though on the ventral faces of lateral lobes or modified pinnules, along a longitudinal axis; and on account of the similarity of texture and the apparent though not indubitable similarity in the nervation of the bract-wing to the lamina and nervation of *Gigantopteris*. The characters of the asymmetrical and unilaterally ribbed lamina or wing-bract, as described above, strongly suggest a modified and reduced pinnule or secondary pinna of a fern-like frond. Such, according to my interpretation, it probably is. Mention has already been made of the deeper dissection of the shortening lobes at the base of some of the large fronds as well as in the young one shown in plate 46, figure 3. As to whether, supposing the seeds to belong to *Gigantopteris*, they were borne on reduced lobes at the bases of the fronds or on special seed-bearing pinnæ cannot at present be ascertained, though it is perhaps more likely that they were distichously and obliquely placed on a short, special rachis, possibly situated in the axil of one of the fronds.

Anticipating that all doubt as to the connection between seed and leaf will later be fully removed, I do not give any other name to this new generic type of seed.

*Supposed polleniferous scales.*—In addition to the seeds which accompany the remains of *Gigantopteris* in the plant beds near Fulda, there are found several examples of a peculiar strobilus. This consists, as shown in figure 4, plate 48, of a rather thick, short axis bearing oppositely two distichous rows of closely placed broadly reniform or broadly ovate-reniform bracts, each about 1 centimeter in length. The bracts, which stand nearly at a right angle to the plane of the axis, partially clasp the latter in an oblique direction and are concavo-convex, the hollow side being downward, as shown in the figures (3 and 4, pl. 48). A border zone of the bracts, many of which are found detached, as shown in plate 49, figure 7, is smooth and bent slightly downward to form a curtain. The inner portion of the bract is thickened, more fibrous, and provided on the lower side with great numbers of small oval pendant sacs, probably for containing pollen, though they possibly are sporangia. The examples seen in plate 49, figure 7, show the convex surface of the bracts with impressions of the sacs. The latter are shown in profile in figure 4, plate 48. The detailed structure of the sac is not clear, but each seems to be somewhat obliquely and separately seated, the vent being an apical or slightly obliquely placed pore.

In many of the detached bracts a radiate nervation is indistinctly shown; but in the bract shown in natural size in plate 48, figure 5, nerves radiate fasciculately from the asymmetrically placed central strand. In another very small and immature specimen, shown in plate 47, figure 3, and enlarged in figure 4, the nervilles appear to anastomose in a greatly elongated mesh comparable to that observed in the fronds already described. The bilateral arrangement of the bracts and their distinctly fern-like nervation leave little doubt as to their filicate or cycadofilic nature. The relation of the strobiles to *Gigantopteris* is made still more probable by the agreement in the peculiar texture and aspect of the residue. I therefore have little hesitation in referring these interesting strobili to the genus *Gigantopteris.* Whether the sacs, whose position and environment are so much like the pollen sacs of *Noeggerathia,* are really pollen sacs, remains in some doubt; but if the associated seeds, described above, also belong to this type, as I believe them to, the bracts bear the pollen sacs (anthers) of the plant, which must be placed with the cycadofilices (pteridosperms). In the latter case the strobiles compose bilateral spikes of the male flowers of *Gigantopteris.*

Mention has already been made of the lobation of the narrowing lamina in some of the leaf fragments collected. Several of the latter have lobes that seem to approach the specimen shown in figure 5, plate 48, in characters; but while they are interesting as illustrating reduction of the lamina in the broad portions of some of the fronds, they do not appear to justify the conclusion that the polleniferous (sporiferous?) bracts of the plant were thus produced, though such was perhaps the case. The aspect of the strobili and the characters of the relatively slender rachis suggest a position, possibly axillary, on the stem of the plant.

## ASSOCIATED SPECIES AND AGE OF THE GIGANTOPTERIS-BEARING BEDS.

*Asiatic distribution.*—The fossils collected from the anthracite mine at Lui-pa-Koú, the type locality of *Gigantopteris,* in the Province of Hu-nan, as described by Schenk [1] are:

1. *Annularia maxima* Schenk.
2. *Calamites,* sp.
3. *Neuropteris flexuosa* Sternberg.
4. *Neuropteris angustifolia* Brongniart.
5. *Cyatheites unitus* Brongniart.
6. *Cyatheites miltoni* Goeppert.
7. *Megalopteris nicotianæfolia* Schenk.
8. *Lepidophyllum,* sp.
9. *Cordaites principalis* Geinitz.

[1] China, vol. 4, 1883, pp. 230–239.

Several of the above-named plants were obviously wrongly identified by Schenk, whose paleobotanical experience had been limited almost entirely to the floras of the Mesozoic. According to his determinations of the fossils the flora should have been referred to the Allegheny or uppermost Pottsville. These species will be further considered together with the plants from Yun-Nan.

The small collections made by the French expedition in southern Yun-Nan, and described in 1907 by Zeiller,[1] are from three localities, (1) Tou-Tza, (2) Sini-Si-Keuou, and (3) I-Ioui-Chao. The species, with their occurrence indicated by the above ordinal numbers, together with references to Zeiller's figures, are as follows:

*Pecopteris* (*Cladophlebis*?), sp., 1 (fig. 6).
*Pecopteris*, sp., 3 (fig. 8).
*Pecopteris* (*Callipteridium*?), sp., 3 (fig. 7, 7*a*).
*Neuropteridium*, cf. *bergense*, 1, 3 (fig. 10).
*Neuropteridium*, sp., 2 (fig. 9).
*Tæniopteris*, sp., 2.
*Tæniopteris*, sp., 3 (figs. 12, 13).
*Tæniopteris*?, sp., 3.
*Gigantopteris nicotianæfolia*, 1, 2, 3 (figs. 14, 15, 15ª, 16).
Cf. *Annularia maxima*, 1 (fig. 17).
*Stigmaria*, sp., 3 (fig. 18).

In connection with his identification of the Yun-Nan fragment with Schenk's *Annularia maxima*, Zeiller points out that it belongs to a different and probably new genus. However that may be, it is interesting to note that the peculiar type figured by Zeiller seems to be exactly represented by several fragments in the Texas collections. Schenk's *Calamites* suggests the forms with very wide ribs figured by Kutorga and Eichwald from the Russian Permian. His *Neuropteris flexuosa* belongs apparently to the *N. planchardi* group, and is compared by Zeiller with *N. matheroni*. It is somewhat suggestive also of the leaflets figured by Zeiller as *Neuropteridium*. The pinnules wrongly placed by Schenk under *Neuropteris angustifolia* appear to represent an undescribed species from beds a little below the Wreford limestone in southern Kansas. Also the fragment of distinctly Mesozoic aspect figured by Zeiller as *Pecopteris*, sp., appears indistinguishable from like fragments found near the horizon of the Winfield formation in Kansas, as well as with *Gigantopteris* near Fulda, Texas. Schenk's pinnæ erroneously placed in *Cyatheites miltoni* and *C. unitus* also have their counterparts in the Western States, though they probably are not confined to the Permian of that region. His *Lepidophyllum* is generically unrecognizable, but his *Cordaites principalis* probably agrees with the specimens referred to that species in both Europe and America. It is somewhat characteristic of the Permian.

A Cladophlebis-like *Pecopteris*, possibly identical with that shown by Zeiller, is present in the Texas Permian, where also is to be found

[1] Résultats de la Mission géologique et minière du Yunnan méridional (Septembre 1903-Janvier 1904); Note sur quelques empreintes végétales des gîtes de charbon du Yunnan méridional, par R. Zeiller, Ann. d. Mines, Paris, ser. 10, vol. 11, 1907, p. 447 et seq., pl. 14.

a form of *Tæniopteris* apparently indistinguishable from that seen in Zeiller's figure 12. A type of *Stigmaria* with very small areoles very similar to that illustrated from western China is present in the Kansas Permian, and has also been found by Zeiller [1] in the collections from Shansi, and by Zalessky [2] in the material from Jantai, near Mukden in Manchuria.

From the foregoing it will be seen that five, and possibly eight, of the species found associated with *Gigantopteris* in the small collections from Hunan and Yun-Nan are present in the Permian of Kansas, Oklahoma, and Texas. It is particularly interesting to note the presence of the singular types illustrated as *Pecopteris*, sp., *Annularia maxima*, and *Tæniopteris*, sp., in association with *Gigantopteris* in Texas. The latter seems to be relatively abundant wherever it is present. On account of the distinctly Mesozoic aspect of *Gigantopteris* and several of the other associated plants the flora from both Yun-Nan and Hunan was regarded by Zeiller as probably middle or lower Triassic, a correlation supported by the presence of an upper Triassic fauna in the superior limestones, and of lower Permian invertebrates in the limestones below the red sandstones that underlie the plant-bearing horizon at one of the Yun-Nan localities. The comparison of the Chinese floras with the material now in hand from the Permian of the Texas-Kansas region shows that the Chinese horizons are in the lower Permian.

As representing other horizons which are probably not far, at most, below the Permian mention may here be made of the collections described by Schenk [3] in the provinces of Sheng-King and Shansi; by Abbado [4] and Zeiller from Shansi; and by Zalessky [5] from the Jantai mines in Manchuria. None of these collections is large, yet they have sufficient in common to show that they do not differ widely in age.

Among the more interesting species collected by Von Richthofen at "Pönn-hsi-hu in Liau-tung" (Liao-tung) in Sheng-King are a *Neuropteris*, possibly identical with *N. matheroni*, *Tæniopteris multinervis*, a Pterophyllum-like fragment, and the *Samaropsis affinis*, which probably belongs to the type of gymnospermous seed known as *Araucarites*. Several of the associated filicoid types, of cosmopolitan aspect, from "Pönn-hsi-hu" occur in the meager collection in Schenk's hands from the anthracite field of "Tsing-Pu-Shan," in southeastern Shansi. The *Tæniopteris multinervis*, which in Europe is unknown below the Permian, was figured by Abbado from "To-Jouan-fu," where it is associated with *Lepidodendron oculis-felis*, a

[1] Ann. d. Mines, Paris, ser. 9, vol. 29, 1901, pl. 7, fig. 88.

[2] Verhandl. kais. russisch. mineral. Gesell., ser. 2, vol. 42, 1905, p. 399.

[3] China, vol. 4, 1883, p. 211.

[4] Palæontographica Italica, vol. 5, 1899, p. 125.

[5] Verhandl. kais. russisch. mineral. Gesell., ser. 2, vol. 42, 1905, p. 385.

type peculiar to this series in China, and several other insufficiently illustrated plants, including Sphenopterids, suggestive of the delicate forms in the Dunkard group in America.

The fragmentary flora from Jantai comprises forms referred by Zalessky to *Odontopteris reichiana, Callipteridium gigas, Pecopteris cyathea, Cordaites principalis,* and *Plagiozamites planchardi,* all characteristic of the lower Permian or highest coal measures of Europe, in company with *Lepidodendron oculis-felis,* and the small form of *Stigmaria* already mentioned. The flora of this, the nearest of the Asiatic localities to the American Continent, is clearly near the Permian-Pennsylvanian border line as pointed out by Zalessky, while, as already remarked, the floras from Shansi and Sheng-King, which are regarded by paleobotanists as approximately contemporaneous, can not be much older; they are certainly uppermost Stephanian, if not actually basal Permian. Those paleontologists and geologists who regard the upper part of the Commentry series in France as Permian can have no doubt as to the reference of all these plant beds to the latter epoch.

From the foregoing it seems probable that the most important coal-producing series in the Paleozoic of China and Manchuria are referable to the lower Permian and perhaps the uppermost Stephanian, there being, as in the western interior and the Appalachian basin of North America, no distinct discordance between the beds of the two epochs.

According to my interpretation the genus *Gigantopteris* is not closely related to any known Paleozoic type. Its nearest, though perhaps very distant, relatives are, I believe, to be found in the fossils described by Morris as *Pecopteris goepperti,* really a *Callipteris,* from the Permian sandstones near Bielebei in the Urals. In fact some of the Russian fossil fragments, such as those shown in figures $2^b$ and $2^c$, on plate A, of the Géologie de la Russie,[1] or the illustrations comprising figures $1^b$, $1^c$ and $1^e$ on plate F of the same great work, have so much in common with our genus, not only as to form but also as to the aspect of the nervation, that, had not Brongniart described the nerves as nonanastomosed, a reexamination of the type material would be suggested in order to ascertain whether, notwithstanding the apparent unity of the succession to the *Callipteris* type of pinna shown in the other illustrations, some of the specimens submitted to Morris and Ad. Brongniart may not really belong to the *Gigantopteris* type. Before passing it may be remarked that the western American collections seem to contain two or three Uralian Permian forms not yet known in western Europe or eastern North America.

[1] Murchison, Verneuil, and Keyserling, Géologie de la Russie et des Montagnes de l'Oural, vol. 2, pt. 3, 1845, pp. 1 and 5.

*The Texas flora.*—In Texas the major part of the Carboniferous system, as divided by the State geological survey, consists, in ascending order, of Millsap, containing Mississippian invertebrates; Strawn, which includes conglomerates and coals of upper Pottsville (lower Pennsylvanian) age; Canyon, mainly marine calcareous beds; Cisco, a coal-bearing formation from which a very few plants, probably of Monongahela age, have been obtained; Albany, Wichita, Clear Fork, and Double Mountain. The latter is unconformably overlain by the Triassic Dockum formation.[1] The Wichita formation has been stratigraphically proven by Adams, Cummins, and Gordon to grade horizontally into the "Albany," of which it represents at least the upper and greater part, the red and variegated sandstones and shales of the former being gradually replaced to the southward by the limestones of the latter. The general geology of the Wichita formation has been recently summarized by Gordon,[2] and the history of paleontological discovery and of opinions, which until very recently have been somewhat conflicting, as to the age of the beds, have been well reviewed by Beede.[3] The Wichita formation is now regarded by all paleontologists as lower Permian, at least in the broad sense (including Artinsk) in which that term is generally employed in western Europe and America.

The "breaks" south of Little Wichita River, 4½ miles southeast of Fulda, i. e., the locality from which the *Gigantopteris* specimens here described were obtained, is some distance above the base of the Wichita, though the interval has not been determined. A stratum in the Missouri, Kansas & Texas Railway cut 1 mile west of Henrietta, supposed to be much lower than the Fulda plant bed, yielded a small flora containing *Walchia* and *Tæniopteris*.

Another locality, "Castle Hollow," 2½ miles south of Fulda, is stratigraphically so near the level of the main Fulda plant bed that its species will be associated with the others in the following provisional list of the fossils. It must, however, be distinctly borne in mind that the identifications in this list are based on a preliminary examination only and that, though of value and interest as closely indicating the character of the flora, they are not in all cases final.

*Preliminary List of the Fossils from the Main Plant Bed (M), and "Castle Hollow" (H), near Fulda, Texas.*

| | |
|---|---|
| *Diplothmema*, sp.?, M. | *Pecopteris*, sp., M. |
| *Pecopteris arborescens*, H. | *Aphlebia*, sp., H. |
| *Pecopteris hemitelioides*, H, M. | ***Odontopteris neuropteroides***, M. |
| *Pecopteris densifolia*?, H. | ***Odontopteris fischeri?*** M. |
| *Pecopteris tenuinervis*, M. | ***Gigantopteris americana***, M, H. |
| *Pecopteris grandifolia*, M, H? | *Neuropteris* cf. *lindahli*, H. |

[1] See Cummins, Tex. Acad. Sci., 1897, pp. 93–98.
[2] Journ. Geol., vol. 19, 1911, p. 110.
[3] Kans. Univ. Sci. Bull., vol. 4, No. 3, 1907.

*Neuropteris cordata*?, M.
***Tæniopteris multinervis***, H, M.
***Tæniopteris abnormis***, M.
***Tæniopteris coriacea?***, M.
*Tæniopteris*, new species, M.
***Annularia spicata***, H.
***Annularia? maxima***, M.
***Sphenophyllum oboratum***, M.
*Sphenophyllum*?, sp., H.
*Sigillaria*, sp., M.
***Sigillariostrobus hastatus***, H.
*Cordaites* cf. *principalis*, M.
***Poacordaites*** cf. ***tenuifolius***, M.
***Walchia piniformis***, M.
***Walchia schneideri?***, H.
***Gomphostrobus bifidus***, H.
***Gomphostrobus?*** sp., M.
*Aspidiopsis*, sp., M.
***Araucarites***, new species, M, H.
*Carpolithes*, sp., H.
Insect wings, M.
*Anthracosia*, M.
*Estheria*, M. H.
Ostracods, M, H.
Fish scales, M, H.

As will be noted on examining the above list, nearly all the species are found in the Permian of Europe or America. The species printed in boldfaced type are characteristic of the Permian. The beds are clearly of lower Permian age.

The red and green sandstones three-fourths mile east, and the beds of similar character about 4 miles southeast of Electra, Texas, contain great numbers of *Gigantopteris* mingled with *Tæniopteris*. In this part, regarded by Gordon [1] as near the top of the Wichita formation, surviving "Coal Measures" ferns have not yet been found.

Several small fragments of *Gigantopteris* which were many years ago transmitted to the United States National Museum [2] from Fort Concho, near San Angelo, Tom Green County, Texas, were examined by Leo Lesquereux, who wrote on the label "Peculiar fern quite unknown to me." The fragments probably represent a new species of the genus.

*The Oklahoma flora.*—The Wreford limestone, which by the Kansas University Geological Survey is made the base of the Permian,[3] is said to be replaced to the southward by arenaceous beds to which the name Payne has been applied by Kirk.[4] Above this sandstone the Permian of Oklahoma is largely composed of red sandstones and shales. Fossil plants were collected from this series at two localities in the State: 1. About 2 miles north of Perry, in chocolate-red and greenish grits regarded by Gould as probably near the horizon of the Winfield formation of Kansas; 2. The McCann quarries in the red sandstone about 2 miles east of Eddy, in Kay County. The latter point, which is well up in the Enid formation,[5] is also known as the source of some of the fossil vertebrates described by Prof. S. W. Williston.

[1] Journ. Geol., vol. 19, 1911, p. 114.
[2] U. S. Nat. Mus., Acc. 7255.
[3] Rept., vol. 9, 1908, p. 77.
[4] Oklahoma Dept. Geol. and Nat. Hist., 3d Bien. Rept., 1904, p. 9.
[5] U. S. Geol. Surv., W. S. Paper 154, 1906.

*Provisional List of the Fossil Plants from Perry (P) and Eddy (E), Oklahoma.*

| | |
|---|---|
| *Diplothmema pachyderma*, E. | *Equisetites*, sp., E. |
| *Pecopteris cyathea*, P. | *Annularia stellata*, P. |
| ***Pecopteris geinitzi***, P. | ***Sphenophyllum obovatum***, E. |
| ***Callipteris***, sp., E. | ***Sphenophyllum*** cf. ***latifolium***, P. |
| ***Gigantopteris americana***, E. P. | ***Sphenophyllum stoukenbergi?*** P. |
| ***Odontopteris*** cf. ***permiensis***, E. | *Sigillaria*, sp.?, P, E. |
| *Neuropteris*, sp., E. | ***Walchia imbricata?*** P. |
| ***Tæniopteris multinervis***, P. E. | ***Walchia*** cf. ***gracilis***, E. |
| ***Tæniopteris abnormis***, P. | ***Araucarites***, sp., P, E. |
| ***Tæniopteris***, sp., E. | *Carpolithes*, E. |
| *Dolerophyllum?*, sp., E. | |

All the species quoted above occur in beds regarded as Permian in the Old World, except two, one of which, *Sphenophyllum obovatum*, is present in the Permian of Kansas (Wellington formation), while the Diplothmema is found in the Dunkard of West Virginia. Several of the Perry species that are known also to occur in the Pennsylvanian have not been found in the higher horizon, at Eddy. The smaller number of filicoid survivors in this flora as compared with the Fulda, Texas, flora is perhaps due to the less distinctly marsh habitat in which they grew and were buried. The *Araucarites* scale-fruit is identical in both regions. As in the preceding list the types distinctly characteristic of the Permian are printed boldface.

It is interesting to note the probable presence in the Oklahoma *Gigantopteris*[1] association of a *Sphenophyllum* and an *Odontopteris* hitherto unknown except in the Uralian region. The fragments of *Tæniopteris* and *Gigantopteris* are very abundant in some of the sandstones at both localities. The evidence for the lower Permian age of these two Oklahoma plant beds needs no further discussion in this place.

*The Kansas Permian plants.*—The fossil plant materials here reported for the first time, in a preliminary way and with provisional determinations of the species, were mostly collected in the course of two short paleobotanical reconnoissance excursions for the purpose (1) of securing fossil plant evidence of a decisive nature relating to the mooted question of the age of the Chase group and Sumner group in Kansas, and of the Wichita formation in Texas; and (2) to procure, if possible, fossil plants in the Rocky Mountain region from the great "red beds" series, over 6,000 feet in thickness, the age of the greater part of which has, on account of failure to yield fossils, been largely the subject of mere supposition. On account of the interesting light some of the forms collected throw on the distribution of a number of plants characteristic of the Uralian region or of western Europe I

[1] The discovery of *Gigantopteris* in Oklahoma, at Perry, is due to the geological interest of Mr. L. L. Hutchison, of that place.

venture here to include several lists of the provisional identifications made in the course of a brief preliminary examination of the material. Full elaboration of the fossil specimens is postponed until additional collections may be made covering a wider stratigraphic as well as geographic range.

The "Big Blue series" in which Prosser[1] classed the Permian of Kansas consists of (1) the Chase group, beginning with the Wreford limestone and ending with the Winfield formation, and (2) the overlying Sumner group, markedly gypsiferous, and composed of the Marion and Wellington formations.

For accounts of the numerous pre-Permian formations and the description of the seven formations of the Chase group as well as of the two in the Sumner the reader is referred to the ninth volume of the Reports of the Kansas University Geological Survey, published in 1909.

Fossil plants were collected by me from the Wreford limestone west of Reece (R); from shales near the Winfield formation northeast of Washington (W); and from the Wellington formation south of Banner (B), and Carlton (C), and east of Salina (S). For the sake of brevity the names are combined in one list in which, by referring to the letters, the floras of the several localities[2] and formations may be integrated.

*List of Species Provisionally Identified from the Permian of Kansas.*

***Schizopteris*** cf. ***trichomanoides,*** W.
*Pecopteris unita.* W.
***Pecopteris pinnatifida,*** W.
***Pecopteris*** cf. ***geinitzii,*** W.
*Pecopteris hemitelioides,* W.
*Pecopteris bucklandi*? W.
*Pecopteris polymorpha,* W.
***Scolecopteris elegans,*** C.
***Cladophlebis*** cf. ***tenuis,*** C.
***Callipteris conferta,*** W, C.
***Callipteris subauriculata,*** S, C, B.
***Callipteris*** cf. ***curretiensis,*** C.
***Callipteris*** cf. ***jutieri,*** R.
***Callipteris*** cf. ***goepperti,*** R.
***Callipteris oxydata,*** S.
***Callipteris whitei,*** B.
***Callipteris lyratifolia?*** S.
***Callipteris*** cf. ***scheibei,*** B.
*Odontopteris brardii* W.
*Odontopteris minor,* W.
***Glenopteris splendens,*** B, C.
***Glenopteris lineata,*** B.
***Glenopteris sterlingi,*** B, C.
***Glenopteris lobata,*** C.
*Neuropteris auriculata*? W.
*Neuropteris odontopteroides,* W.
*Neuropteris scheuchzeri,* var., W.
*Neuropteris permiana,* W.
***Taeniopteris multinervis,*** W.
***Taeniopteris coriacea,*** B, C.
***Taeniopteris coriacea,*** var. ***linearis,*** B, C.
***Sphenophyllum obovatum,*** C, B.
***Sphenophyllum*** cf. ***stoukenbergi,*** W.
***Sphenophyllum*** cf. ***thonii,*** W.
***Sigillariostrobus hastatus,*** R.
*Noeggerathia*? new species, B.
*Cycadospadix*? sp., C.
*Cordaites principalis,* R.
***Poacordaites linearis?*** C.
***Walchia piniformis,*** R.
***Walchia*** cf. ***filiciformis,*** R.
***Walchia,*** sp., C.
***Voltzia,*** sp. C.
***Ullmannia?*** sp., C.
***Schützia?*** cf. ***anomala,*** R.
***Araucarites?*** sp., C.
*Rhabdocarpos,* new species, R.
*Carpolithes,* sp., S. B.

[1] Journ. Geol., vol. 10, pp. 703-737.

[2] For exact descriptions of the localities and for excellent descriptions of many of the species, see the paper by E. H. Sellards in the State Survey volume cited.

All the specifically identified plants in the above list are found in beds referred to the Permian in their respective provinces, most of them being European. The species and types in bold face are diagnostic of the Permian.

An inspection of the rather short list from the Wreford limestone reveals a flora, most of whose species are characteristic of the Permian, a small percentage only being common to the "Coal Measures." It is in fact somewhat surprising to note so few pre-Permian forms in this flora. On the other hand, at the Washington locality, the horizon of which is near the Winfield formation, a considerable number of Pennsylvanian survivors are present in the Carbonaceous muds, evidently the remains of an old swamp where they seem to have found refuge, perhaps making their last stand. But even these, nearly every one of which survived in the Permian of the Old World, are accompanied by a sufficient number of characteristic European Permian types clearly to show the Rothliegende age of the beds. The more ample material therefore confirms the conclusions reached by Sellards,[1] and substantiates the early opinions expressed by the present writer.[2]

The Wellington flora is characterized by an abundance of *Callipteris* forms and by great numbers of *Tæniopteris* and *Glenopteris*, to which are added types probably referable to *Ullmannia*, *Voltzia*, and *Araucarites.* The singular fronds of *Glenopteris*, doubtless a Cycadofilic, have many points of similarity to the Mesozoic *Cycadopteris* and *Lomatopteris*, as has been pointed out by Sellards. The relatively simple form of the leaves and the thick leathery texture are xerophytic characters strongly suggestive either of long dry seasons or a climate more arid in general than that of the earlier series.

*The Colorado flora.*—In Colorado the search for plants in the "Red Beds" was confined to two points: Fairplay and the Canyon of the Arkansas River below Salida. At the former locality an unsuccessful effort was made to rediscover the point at which Prof. Arthur Lakes in 1883 collected plants and insects.

Plants were located by myself in buff and dark Carbonaceous shales nearly 4 miles southwest of Fairplay, the locality and horizon being not far, as subsequently ascertained, from the plant bed discovered by Professor Lakes.

It will be remembered that the early collection was placed in the hands of Lesquereux, and the insects were submitted to Scudder. The former [3] pronounced the beds Permian, while the latter [4] adjudged them to be Triassic, and so confidently and emphatically reiterated

[1] Kans. Univ. Quart., vol. 9, 1900, p. 179. Report Kans. Univ. Geol. Surv., vol. 9, 1909, p. 462.

[2] Bull. 211, U. S. Geol. Surv., 1903, p. 117.

[3] Bull. Mus. Comp. Zoöl. Harvard Univ., vol. 7, 1883, p. 244.

[4] Mem. Boston Soc. Nat. Hist., vol. 4, No. 12, 1890, p. 457.

the Triassic correlation that the bed has become known as an important source of Triassic insects in America. A portion at least of the material examined by Lesquereux now rests in the Lacoe collection in the United States National Museum. Probably it belongs to a horizon somewhat higher than the fossils collected by myself. I therefore designate the Lesquereux species A, those collected by myself being marked B in the following list:

*Provisional List of Plants from Fairplay, Colorado.*

***Sphenopteris schimperiana?*** B.
***Sphenopteris lebachensis*** Weiss, A.
*Sphenopteris dentata* F. and I. C. W., A.
***Sphenopteris gutzholdi*** Gutbier, A.
***Pecopteris pinnatifida*** Gutbier, B.
*Pecopteris foeminaeformis* (Schlotheim) Zeiller., A.
*Pecopteris arborescens* (Schlotheim) Brongniart, B.
*Pecopteris* (Danaeites Göppert), sp., B.
***Scolecopteris elegans*** Gutbier, B.
***Callipteris*** cf. ***hymenophylloides*** Weiss, A.
***Callipteris*** cf. ***lyratifolia*** (Göppert), B.
*Odontopteris subcrenulata* Rost, B.
*Neuropteris auriculata* Germar, B.
***Calamites kutorgae?*** B.
***Sphenophyllum obovatum*** Sellards, B.
*Sigillaria?* sp., B.
***Sigillariostrobus hastatus,*** A, B.
*Poacordaites*, sp., A.
***Walchia piniformis*** (Schlotheim), A, B.
***Walchia hypnoides,*** A, B.
***Walchia gracilis?*** A.
***Ullmannia,*** sp., A, B.
***Voltzia,*** sp., A.
***Araucarites,*** sp., A, B.
***Gomphostrobus bifidus,*** B.

As in previous lists, the types distinctly indicative of Permian age are in boldface type. All of the forms that occur in rocks of Pennsylvanian age have also been found in formations regarded by all as Permian. The evidence of the Sphenopteris, the Callipteris, and of the gymnosperms leaves little room for doubt that this flora is of Permian age, probably Rothliegende.

In the Canyon of the Arkansas near Wellsville Station a lower group of sandstones, limestones, and thin coals contains fossil plants of Pottsville age. This belt of basal Pennsylvanian rocks in similar composition, with coals and similar plants, appears to extend from the region of Pecos City, New Mexico, northward to the vicinity of Manitou, Colorado, and probably farther. It is unconformable, at least locally, on older formations. A thin series, largely limestone, which follows next at Wellsville, verges rapidly into the "Red Beds" series. The latter carries lower "Coal Measures" plants about 900 feet above its base; and near a thin coal, about 1,100 feet higher, a few fragments were found which seem to indicate a very high place in the Pennsylvanian.

Near the south portal of the railway tunnel, probably 800 feet above the horizon last mentioned, or about 2,800 feet above the base of the "Red Beds" series, a small but interesting flora was obtained, which leaves little doubt as to the Permian age of its horizon.

*List of Plants from the Denver and Rio Grande Tunnel Below Swissvale, Colorado.*

| | |
|---|---|
| ***Callipteris***, sp. | ***Sigillariostrobus hastatus.*** |
| ***Psygmophyllum*** cf. ***cuneifolium.*** | ***Walchia*** cf. ***piniformis.*** |
| *Odontopteris subcrenulata* Rost? | *Walchia* cf. *imbricata.* |
| *Macrostachya*? sp. | *Rhabdocarpos dyadicus* Geinitz? |

From beds apparently about 1,550 feet higher between Badger Creek and the Wellsville "One mile" signal beds were located containing *Schizopteris, Callipteris, Odontopteris, Walchia,* and *Rhabdocarpos.* It is therefore probable that 2,000 feet, at least, of this section of the "red beds" is Permian.

Fragmentary and incompletely representative of the several floras as the lists may be, they yet show some interesting aspects of the distribution of the Permian species. Thus, the genus *Walchia,* unknown in the Permian of the Appalachian trough, is present at most of the localities, while *Callipteris,* which is very meagerly represented in eastern North America, is common and highly differentiated in Kansas and Colorado. *Gomphostrobus,* another type characteristic of the Permian of western Europe and hitherto unknown in North America, is present in Kansas, Colorado, Oklahoma, and Texas. The common type of simple leafed *Tæniopteris,* diagnostic of the western European lower Permian, is nearly everywhere present, sometimes accompanied by other forms, one of which, with distant, simple nerves, is of distinctly Mesozoic aspect.

In addition to the many *Callipteris* and *Walchia* species just mentioned, the provisional lists from the western Permian include a number of other forms near to, if not identical with, diagnostic Old World Permian types hitherto unknown in this continent. Among these are *Schizopteris* cf. *trichomanoides, Sphenopteris lebachensis, Pecopteris geinitzi, Pecopteris pinnatifida, Cladophlebis*? cf. *tenuis, Scolecopteris elegans, Odontopteris subcrenulata, Tæniopteris abnormis, Annularia spicata, Rhabdocarpos* cf. *dyadicus.*

It is probable that several cosmopolitan species of *Pecopteris* and *Sphenopteris* will be found to have accompanied *Tæniopteris multinervis* from western Europe to eastern China.

The examination of the materials from the Western Interior and Rocky Mountain basins shows that while the flora is composed mainly of types common to western Europe which have undoubtedly been distributed along essentially the same northeastern Arctic-American route by which the Pennsylvanian floras migrated, it contains also a somewhat unique element unmistakably derived from eastern Asia. The latter includes the *Gigantopteris,* the peculiar *Annularia,* and a *Tæniopteris* form, to which should possibly be added the representatives of *Araucarites* and *Neuropteridium.* The migration of this land plant element was very probably by the north Pacific.

The most important deduction to be drawn from the occurrence of *Gigantopteris* and its particular associates in North America is the essential continuity of environmental conditions indicated thereby. The vital conditions under which the types lived in Oklahoma and Texas can not have been very far different in their essential respects from those prevailing in the Chinese habitats of the types. Environmental conditions sufficiently uniform to enable these plants to thrive must have attended the route of their land migration. We may therefore conclude that a climatic environment essentially similar extended from China to western North America; that is, that during *Gigantopteris* time western North America and portions of eastern Asia were probably included in the same climatic province. The mingling of the western European flora with the Chinese elements in Oklahoma and Texas suggests that the latter region may have been on the eastern border of the province.

Another interesting feature of the western Permian is the presence of fronds possibly identical with *Psygmophyllum cuneifolium*, *Odontopteris permiensis*, *Odontopteris fischeri*, and *Sphenophyllum stoukenbergi*, species that seem not to have been known outside of the Uralian region, from which they were described. Possibly the remarkable Kansas type described by Sellards[1] as *Glenopteris*, which is unlike any European type of its period, and which may be nearest related to the *Neuropteris salicifolia* of Morris, also is of Uralian or Asiatic descent. The types of Uralian origin also may have reached western North America by the north Pacific route.

According to their composition and relations the floras of the younger Carboniferous in Shansi and Sheng-King, or Manchuria, which are either at the latest Pennsylvanian stage or in the early Permian, may with probable safety be assumed to have antedated the early Gondwana glaciation and the existence of the *Gangamopteris* flora in southern Asia. The question arises, then, whether the floral peculiarities of the *Gigantopteris* province are due in part to climatic changes leading to refrigeration in India, and whether later the climate of the *Gangamopteris* province extended over a portion at least of the *Gigantopteris* province, and if so, whether it did not cover a part of western North America.

## CONCLUSIONS.

The genus *Gigantopteris* Schenck, common in the Permian "Red Beds" of Texas and Oklahoma, is a plant with large sympodially(?) dichotomous pinnæ, and confluent (and thus elongately meshed) Goniopteroid nervation. It is in many respects strongly suggestive

[1] Kans. Univ. Quar., vol. 9, 1900, p. 179.

of *Callipteris goepperti* Morris, which may be its nearest known relative.

On the evidence of association, bract texture, and nervation, certain obovate seeds borne in the ventral faces of rather large, cuneate-obovate, distantly distichous bracts, and representing a new generic type of fructification, are regarded as the probable fruits of *Gigantopteris.* Likewise, certain strobili, composed of two opposite rows of distally concavo-convex reniform disks, bearing on their under surfaces numerous pendant oblong sacs are on account of the agreement in the texture and filicoid nervation of the disks with the lamina and nervation of *Gigantopteris,* provisionally referred, with a high degree of probability, as the polleniferous strobili of that genus.

The genus *Gigantopteris* is therefore regarded as a cycadofilic (Pteridospermic) type.

In China (provinces of Hun-Nan and Yun-Nan) *Gigantopteris* is associated with certain European Permian forms and a number of American types, all showing the Permian age of the *Gigantopteris* bearing beds.

The very incomplete collections of fossil plants from the Wichita formation in Texas, from its supposedly approximate equivalents in Oklahoma, from the Chase and Sumner groups in Kansas, and from the great series of undifferentiated "Red Beds" in the Rocky Mountain region of southern Colorado, show a mixed flora embracing (1) mainly representatives of the Permian flora of western Europe, and including many types not previously known in North America; (2) a smaller portion peculiar to the *Gigantopteris* association in south central, and southwestern China; and (3) several types apparently identical with or very close to forms hitherto known only in the Permian of the Uralian region.

The distribution of the floral elements indicates that the western European or cosmopolitan elements of the flora migrated between North America and Europe, presumably by the same general northeastern route as that followed by their Pennsylvanian predecessors, while the distinctly Chinese types must have come to Texas and Oklahoma by the north Pacific (Alaskan) route, by which the related Uralian forms may also have migrated. Since the land migration of the Chinese types could hardly have been accomplished without the aid of essential continuity of environmental conditions, and since it is probable that the *Gigantopteris* elements lived under climatic conditions mainly similar in both Texas and China, the conclusion appears justified that the climatic province under which they thrived in Asia extended to western North America and that it included the region of north Pacific migration. The mingling of western European species with *Gigantopteris* in the southwestern "Red Beds" is construed to indicate that this region was probably on the eastern border of the *Gigantopteris* province.

The *Gigantopteris* flora (early Permian) very probably preceded the development of the *Gangamopteris* flora in southern Asia. Did the *Gangamopteris* (Permian) flora, which came by an Antarctic route to southern South America, ever follow the *Gigantopteris* flora by the northern route into western North America? The extension of the eastern Asiatic province to the western border of this continent in *Gigantopteris* time, and the reported presence of *Glossopteris*, a survivor of the *Gangamopteris* flora in the Mesozoic of western Mexico, makes it seem not impossible that the *Gangamopteris* flora also may have reached North America. In view of the almost total lack of paleobotanical knowledge concerning the Pennsylvanian and Permian rocks of all North America west of the Rocky Mountains, it will readily be recognized that the *Gangamopteris* flora may be present, though it may be a long time before paleontological exploration will have been carried so far as to unearth its remains.

## EXPLANATION OF PLATES.

### Plate 43.

*Gigantopteris americana.*

Young frond showing nearly equal division and slight constriction at the point of dichotomy. The border of the lamina in this specimen is seen to be sometimes concave, sometimes convex, opposite ends of the secondary nerves.

(Cat. No. 34070, U.S.N.M. Photographed in natural size.)

### Plate 44.

*Gigantopteris americana.*

Fragment of leaf in which the incomplete lamina appears to be gradually narrowed downward, becoming slightly lobate at the same time. The basal portion of the lamina, which is slightly macerated, has been destroyed.

(Cat. No. 34069, U.S.N.M. Photographed in natural size.)

### Plate 45.

*Gigantopteris americana.*

Portion of large leaf showing the union of two lobes far above the point of dichotomy, with very little constriction at the sinus. The border is seen to be convex opposite the secondary nerves in the upper part of the division on the right. The secondary nerves are opposite to alternate.

(Cat. No. 34071, U.S.N.M. Figure reduced to $\frac{4}{5}$ natural size.)

### Plate 46.

*Gigantopteris americana.*

Fig. 1.—Fragment of a relatively slender lobe showing the Goniopteroid aspect of the margin and nervation. The sutural nerves are evident in this young pinna, and the border is concave opposite the ends of the secondary nerves, probably as the result of slight shrinkage.

(Cat. No. 34062, U.S.N.M. Photographed in natural size.)

Fig. 2.—Fragment from the lower part of a leaf showing the nervation which is more characteristically represented in the middle of the enlarged illustration.

(Cat. No. 34074, U.S.N.M. Figure twice natural size.)

Fig. 3.—Two young leaves, one bifurcated and gradually narrowed downward, the other abruptly constricted at the base of the lamina and petiolate. On the left is seen the base of a partly grown leaf, while on the right is shown a fragment of a leaf, perhaps fully grown.

(Cat. No. 34073, U.S.N.M. Photographed in natural size.)

PLATE 47.

*Gigantopteris americana.*

Fig. 1.—Fragment of a leaf of average size illustrating the dicotyledonous aspect of many of the examples. In portions of the specimen the conditions of maceration have brought the nervation into high relief, as photographically represented. The base of the fragment is probably near the point of bifurcation.

(Cat. No. 34072, U.S.N.M. Figure in natural size.)

Fig. 2.—Photographic enlargement, showing the nervation of a leaf slightly larger than that seen in figure 1. On the left is seen the secondary nerve, on the right the sutural nerve. A part of the same specimen is shown in natural size in the nature print in plate 48, figure 2.

(Cat. No. 34061, U.S.N.M. Photograph, twice the natural size.)

Fig. 3.—Immature scale detached from a strobilus of the type shown in plate 48, figures 3 and 4. It is probably the polleniferous scale of *Gigantopteris americana.*

(Cat. No. 34066, U.S.N.M. Illustrated in natural size.)

Fig. 4.—The same specimen photographed twice the natural size to show the *Gigantopteris* nervation of the immature scale. The inner convex portion corresponds to the polleniferous (?) area of the scales seen in plates 48 and 49.

PLATE 48.

*Gigantopteris americana.*

Fig. 1.—Apex of leaf illustrating the dicotyledonous aspect of the fragments.

(Cat. No. 34063, U.S.N.M. Figure in natural size.)

Fig. 2.—Photographic print made from a carbon-paper impression of the surface of a leaf fragment to show the nervation. The nature print serves excellently to illustrate the aspect of the nervilles and the thin sutural nerves.

(Cat. No. 34061, U.S.N.M. Figure in natural size.)

Fig. 3.—Strobilus supposed to comprise the polleniferous disks of the same plant. The specimen is broken slightly obliquely to the axis so that the upper convex surfaces of the distichous scales or bracts are seen in the upper part of the figure, while the under concave surfaces are shown in the fragments lying beyond the plane of the axis in the lower part of the photograph. The polleniferous (?) sacs are imperfectly seen at a few points on the underside of the bracts.

(Cat. No. 34077, U.S.N.M. Figure, natural size.)

Fig. 4.—Similar strobilus, broken longitudinally along the axis. Numerous polleniferous (sporiferous?) sacs are shown on the underside of the bracts, the borders of which are bent downward.

(Cat. No. 34078, U.S.N.M. Figure in natural size.)

Fig. 5.—Lobe bract, similar to the fertile bracts of the strobilus, showing *Giantopteris* nervation. This specimen is comparable to that seen in figure 3 on plate 47.

(Cat. No. 34075, U.S.N.M. Photograph, natural size.)

Fig. 6.—Similar bract strongly concavo-convex, partially clasping the axis, and showing a nervation apparently in agreement with that of the *Gigantopteris* sterile frond.

(Cat. No. 34067, U.S.N.M. Figure, natural size.)

PLATE 49.

*Gigantopteris americana.*

Fig. 1.—Fruit from which the thin outer envelope (wing, or lamina) has been partially broken away, exposing the flattened nutlet, which has a thin sclerotic test.

(Cat. No. 34081, U.S.N.M. Photographed in natural size.)

Fig. 2.—Seed attached to axis. The photograph shows the asymmetrical form of the fruit, the narrow keeled rib at the lower border, and the nervation radiating from the point of attachment. The small roundish body in the upper part of the nucellus may be interpreted as a megaspore. The lamina wing is puckered about the micropylar region.

(Cat. No. 34082, U.S.N.M. Figure, natural size.)

Fig. 3.—Seed covered by the wing lamina in which the nervation, apparently in accord with that of *Gigantopteris*, is indistinctly seen. The nutlet is slightly apiculate.

(Cat. No. 34083, U.S.N.M. Photograph, natural size.)

Fig. 4.—Seed in which the outline of the nutlet is indistinctly seen beneath the wing lamina, which, as in the other specimens, is narrowly ribbed on one side (left), radiately nerved, and puckered about the micropylar region.

(Cat. No. 34064, U.S.N.M. Figure, natural size.)

Fig. 5.—Seed in which the nervation of the wing lamina, radiating from the point of attachment, and the lateral rib are more distinctly shown.

(Cat. No. 34079, U.S.N.M. Illustrated, natural size.)

Fig. 6.—Seed dimly outlined beneath the wing lamina. The broken lateral rib is shown on the right, and the nervation is indistinctly seen along the upper border of the wing.

(Cat. No. 34068, U.S.N.M. Figure, natural size.)

Fig. 7.—Detached fertile scales of the type shown in figures 3 and 4 on plate 49. The photograph shows the upper or convex surface through which the impressions of the supposed pollen sacs lying underneath the scales are brought into relief. The border zone of these specimens is the same as that shown in figure 5, plate 48, and figures 3 and 4 on plate 47.

(Cat. No. 34076, U.S.N.M. Illustrated, natural size.)